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Specification

1. Title of Invention:

Manufacturing method of display device

2. What is Claimed

A manufacturing method of an active matrix display device wherein a pixel electrode is turned ON/OFF by a thin film transistor, comprising;

a process forming an amorphous silicon film on a transparent substrate;

a process irradiating a first pulsed laser beam to apply heat to said amorphous silicon film for crystallization;

a process forming a gate insulating film and a gate electrode on said crystallized silicon film; and

a process forming a source region and a drain region of said thin film transistor by diffusing an impurity into said crystallized silicon film by irradiating a second pulsed laser beam to said crystallized silicon film after depositing said impurity on said crystallized silicon film, or in a gas containing said impurity.

3. Detailed Description of Invention

[Field for Industrial Use]

The present invention relates to a manufacturing method of display device which is suitable, for example, for the application in the manufacturing of an active matrix type liquid crystal display.

[Abstract of the Invention]

The present invention, in a manufacturing method of an active matrix type display device wherein a pixel electrode is turned ON/OFF by a thin film transistor, comprises a process an amorphous silicon film is formed on a transparent substrate, a process irradiating a first pulsed laser beam to apply heat to said amorphous silicon film for crystallization, a process forming a gate insulating film and a gate electrode on said crystallized silicon film, and a process forming a source region and a drain region of said thin film transistor by diffusing an impurity into said

crystallized silicon film by irradiating a second pulsed laser beam to said crystallized silicon film after depositing said impurity on said crystallized silicon film, or in a gas containing said impurity. By this, a high-performance thin film transistor can be manufactured using a cheap glass substrate or resin substrate, and in addition, the source region and the drain region of this thin film transistor can be formed self-alignedly in relation to the gate electrode. Also, the manufacturing processes of the display device can be simplified.

[Prior Art]

Conventionally, an active matrix type liquid crystal display device which turns ON/OFF its pixel electrodes by thin film transistors formed in the respective pixels, has been known. Fig. 5 A and Fig. 5 B indicate an example of a conventional active matrix type liquid crystal display. As indicated by Fig. 5 A and Fig. 5 B, in this liquid crystal display, on a transparent glass substrate (101), a pixel electrode (102) made of ITO (Indium Tin Oxide), a thin film transistor (T) to turn ON/OFF this pixel electrode (102), a gate bus line (103) and a source bus line (104) are formed. Said thin film transistor (T) is constituted by a gate electrode (105) which is formed in the same body with said gate bus line (103), a gate insulating film (106) such as an SiO_2 film (or SiN film), an intrinsic (I-type) hydrogenated

amorphous silicon (a-Si:H) film (107) and a source region (108) and a drain region (109) made of an n^+-type a-Si:H film. In this case, the source region (108) is connected to said source bus line (104) and the drain region (109) is connected to said pixel electrode (102) by a metal line (110) such as aluminum (Al). Also, in Fig. 5 A, said gate insulating film (106), a-Si:H film (107), source region (108) and drain region (109) are omitted.

As for a technical reference of the prior art relative to the present invention, a patent official gazette, Laid-Open #: Sho61-249080, which relates to a liquid crystal display element wherein a pixel electrode is formed by a semiconductor layer containing oxygen (O) or nitrogen (N) can be referred.

[Problems the Present Invention Attempts to Solve]

The transistor (T) of the aforementioned conventional active matrix type liquid crystal display is formed using the a-Si:H film (107). This a-Si:H film (107) can be formed on the glass substrate (101) which is not thermally resistive by employing a plasma CVD method. However, the mobility of carriers (electrons) in this a-Si:H film (107) can hardly be said sufficiently high. Also, since the source region (108) and the drain region (109) of this thin film transistor (T) cannot be formed self-alignedly in relation to the gate electrode (105), the alignment accuracy

between these source region (108) and drain region (109) and the gate electrode (105) is poor. Furthermore, so many lithography processes are required, from the formation of the pixel electrode (102) through the formation of the source bus line (104) and to the wiring (110), thus the manufacturing processes are complex.

Therefore, the object of the present invention is to provide a manufacturing method of a display device which allows to fabricate a high-performance thin film transistor with high carrier mobility using a cheap glass substrate or resin substrate.

Another object of the present invention is to provide a manufacturing method of a display device wherein the source region and drain region of a thin film transistor can be formed self-alignedly in relation to the gate electrode.

Still further object of the present invention is to provide a manufacturing method of a display device wherein the manufacturing processes can be simplified.

[How to Solve the Problems]

The present invention is a manufacturing method of a display device which is a manufacturing method of an active matrix display device wherein a pixel electrode (13) is turned ON/OFF by a thin film transistor (T), comprising a process forming an amorphous silicon film (3) on a transparent substrate (1), a process irradiating a first

pulsed laser beam (5) to apply heat to said amorphous silicon film (3) for crystallization, a process forming gate insulating films (4, 7) and a gate electrode (10) on said crystallized silicon film, and a process forming a source region (12) and a drain region (13) of said thin film transistor (T) by diffusing an impurity into said crystallized silicon film (6) by irradiating a second pulsed laser beam (5) to said crystallized silicon film (6) after depositing said impurity on said crystallized silicon film, or in a gas containing said impurity.

[Operation]

According to the above method, since the thin film transistor can be formed by the crystallized silicon film, the mobility of carriers can be increased. Moreover, the formation and crystallization of the amorphous silicon film, the impurity doping for the formation of the source region and drain region can be performed at a low temperature from room temperature to around 300°C. Therefore, a high-performance thin film transistor can be manufactured using a cheap glass substrate or resin substrate. Also, by irradiating the pulsed laser beam, the impurity is doped into the silicon film self-alignedly in relation to the gate electrode, so that the source region and drain region of the thin film transistor can be formed self-alignedly in relation to the gate electrode. In addition, since a

lithography process is not required for the formation of the source region and drain region as in the conventional method, the number of the lithography processes can be reduced at least by this amount, thus the manufacturing processes can be simplified.

[Embodiment]

Hereafter, one embodiment of the present invention is explained in accordance with figures. This embodiment is a case where the present invention is applied to a manufacturing method of an active matrix type liquid crystal display.

Fig. 1 A through Fig. 1 D indicate the process flow of the manufacturing method of the active matrix type liquid crystal display in the embodiment of the present invention, and Fig. 2 shows its finished state. Fig. 1 A through Fig. 1 D are cross sectional views taken along the line Y-Y in Fig. 2.

In this embodiment, as indicated in Fig. 1 A, fist, on a glass substrate (1) which has been cleaned beforehand, an SiN film (2) for example, in a film thickness of, for example, around 300Å, an I-type a-Si:H film (3) for example, in a film thickness of, for example, from 300 to around 1000 Å, and an SiN film (4) for example, in a film thickness of, for example, around 1000Å, are sequentially formed by, for example, a plasma CVD method at a substrate temperature, for

example, from room temperature to around 300°C. By said SiN film (2), the contamination from the glass substrate can be prevented.

Next, for example, at room temperature, a pulsed laser beam (5) is irradiated on the entire surface. As for this pulsed laser beam, for example, the pulsed laser beam (wavelength 308nm) by XeCl excimer laser can be used, and the pulse width thereof is, for example, 30ns, the irradiation energy density is, for example, 200 to 300nJ $/cm^3$. By the irradiation of this pulsed laser beam (5), said a-Si:H is heated instantaneously and crystallized. By this, as indicated in Fig. 1 B, a polycrystalline Si film (6) can be formed. Next, said SiN film (4) and this crystallized Si film (6) is patterned by etching to form an island pattern which is an incorporated body of a later-described thin film transistor and an Si film for forming a pixel electrode (13). Next, by a plasma CVD method for example, an SiO_2 film (7) is formed in a film thickness of, for example, 1000 to 2000Å, and thereafter, on this SiO_2 film (7), an Al film (8) is formed in a film thickness of, for example, 1000 to 2000Å by a spattering method or vapor deposition method.

Next, these Al film (8) and SiO_2 film (7) are patterned into a specified shape by etching to form a gate bus line

(9) and a gate electrode (10) as indicated in Fig. 1 C and Fig. 2. Then, using this patterned SiO_2 film (7) as a mask, said SiN film (4) is etched off to expose said Si film (6). A gate insulating film is constituted by the SiN film (4) and said SiO_2 film (7) after this patterning. Next, by a plasma CVD method for example, on the entire surface, a phosphorus (P) film (11) in a film thickness of, for example, 100Å is formed, and thereafter, by a pulsed laser beam (5) by, for example, XeCl excimer laser is irradiated on the entire surface. The pulse width of this pulsed laser beam (5) is, for example, 20ns, and the irradiation energy density is, for example, 200 to 300mJ/cm^3. By the irradiation of this pulsed laser beam (5), said Si film (6) is heated instantaneously, and as a result, into said Si film (6) with which said P film (11) is in direct contact, P is doped self-alignedly in relation to said gate electrode (10). By this, for example, an n^+-type source region (12) and an n^+-type pixel electrode (13) which also acts as, for example, drain region, is formed self-alignedly in relation to said gate electrode (10). The resistance ρ of these source region (12) and pixel electrode (13) which also acts as the drain region, can be made as low as 10^{-2} to $10^{-4}\Omega \bullet cm$. Also, as explained later, the transmittance characteristic of this pixel electrode (13) for visible light with

wavelength of 300 to 800nm is desirable. Thereafter, said P film (11) is etched off. The impurity doping method such as above described is what is called LIMPID (Laser Induced Melting of Predeposited Impurity Doping).

Next, as indicated in Fig. 1 D, on the entire surface, an interlayer insulating film (14) such as photosensitive polyimide is formed in a film thickness of, for example, 0.15 to 1 μm, and thereafter, a specific region of this interlayer insulating film (14) is removed to form a contact hole (14a). Next, after an Al film for example, is formed on the entire surface, this Al film is patterned into a specific pattern by etching to form a source bus line (15). This source bus line (15) is connected to said source region (12) through said contact hole (14a). Next, after a liquid crystal alignment layer (not indicated in the figures) is formed on the entire surface, in order to improve the characteristic of the interface between the SiN film (4) and the Si film (6) and voltage resistivity of the interlayer insulating film (14) or the like, annealing is performed at a temperature, for example, 300 to 400°C as necessary. Thereafter, through the liquid crystal sealing process and the like, an objective liquid display is completed.

In a liquid crystal display manufactured in this manner, the n-channel thin film transistor (T) is constituted by said gate electrode (10), the gate insulating film comprised

of said SiN film (4) and SiO_2 film (7), said source region (12) and the drain region which is also used as the pixel electrode (13).

Fig. 3 indicates the transmittance spectrum of an as-deposited a-Si:H film (film thickness : 550Å) and that of the a-Si:H film after crystallization by the irradiation of the pulsed laser beam, and Fig. 4 indicates the wavelength dependency of the absorption coefficient calculated by the transmittance spectrums in Fig. 3.

As it can be understood from Fig. 3, the as-deposited a-Si:H film does not transmit much of blue ray, but transmits green and red rays very well, therefore, the film color looks brown. On the other hand, after this a-Si:H film is crystallized by the irradiation of the pulsed laser beam, as it can be seen in Fig. 4, the absorption coefficient is reduced especially for the blue to green rays, therefore, as it can be seen also in Fig. 3, the transmittance of the crystallized Si film for blue ray is increased, thereby gaining a high transmittance from 35 to 45% for the three primary colors, red, green and blue. As a result, the Si film (6) having a superior white transparent color in the visible region can be obtained. The aforementioned value of the transmittance from 35 to 45% is low when compared to that of ITO (refer Fig. 3), however, it is a sufficient

value for the practical use. Also, by forming an antireflection film such as, for example, an SiN film on the crystallized Si film (6) to restrain the reflection, it is possible to improve the transmittance to, for example, around 80%.

The present invention yields the following various benefits. That is, the crystallization of the a-Si:H film (3) can be performed at room temperature by the irradiation of the pulsed laser beam (5). Also, the impurity doping to form the pixel electrode (13) which also acts as the source region (12) and the drain region can be performed similarly at room temperature by the irradiation of the pulsed laser beam (5). Therefore, according to the present invention, the high-performance thin film transistor (T) with high carrier (electron) mobility can be manufactured by low-temperature processes from room temperature to around 300°C using a glass substrate (1) which is not thermally resistive, but cheap. By this thin film transistor (T), high-speed switching with a large electric current can be performed. Also, it, not only allows to form the Si film for thin film transistor (T) formation and the pixel electrode (13) by a single lithography, but also requires less number of lithography processes compared to that of the aforementioned conventional liquid display since it does not require a lithography process for the formation of the

source region (12) and the drain region which is also used as the pixel electrode (13), thus the manufacturing processes can be simplified to this extent. Moreover, since the impurity is doped into the Si film (6) self-alignedly in relation to the gate electrode (10), the source region (12) and the pixel electrode (13) which also acts as the drain region can be formed self-alignedly in relation to the gate electrode (10).

Furthermore, since the Si film for the thin film transistor (T) and the pixel electrode (13) are constituted by the common thin Si film (6), the overall surface is flat, thereby preventing the line breaks in the gate bus line (9) and the source bus line (15).

Heretofore, the present invention has been explained in detail, however, the present invention is not limited to the above embodiment, and various altered forms based on the technical concept of the present invention are possible.

For example, instead of using the a-Si:H film (3), an a-Si_xC_{1-x}:H ($0<x<1$) film, an a-Si_xN_{1-x}:H ($0<x<1$) film, an a-Si_xO_{1-x}:H ($0<x<1$) film or the like can also be used. Since these a-Si_xC_{1-x}:H, a-Si_xN_{1-x}:H, and a-Si_xO_{1-x}:H films have their absorption edges nearer to the shortwave side compared to the a-Si:H film, the transmittance in the visible region can be increased. Also, the concentration of these C, N and O

can be made, for example, about $10^{19}cm^{-3}$, and this enables to reduce the absorption coefficient in the visible region down to 10^5cm^{-1} or lower. Also, these a-Si_xC_{1-x}:H, a-Si_xN_{1-x}:H and a-Si_xO_{1-x}:H films can be formed using, for example, $C_2H_2CH_3$, NH_3 and NO_2 respectively, as a reaction gas, besides SiH_4, during the growth by a plasma CVD method. Moreover, since the high transmittance is required for the pixel electrode (13), for example, the C, N or O can be added by the aforementioned LIMPID method to the a-Si:H film (3) after it is formed. In addition, this a-Si:H film (3) is not necessarily required to be formed by a plasma CVD method, and it can be formed also by a spattering method or vapor deposition method. Furthermore, as for the impurity doping method for the formation of the source region (12) and the pixel electrode (13) which also acts as the drain region, the GILD (Gas Immersion Laser Doping) method wherein the impurity doping is performed by irradiating a pulsed laser beam in a gas containing an impurity to be doped (for example, where an n-type impurity is intended, PH_3, and where a p-type impurity is intended, B_2H6), can be employed.

Moreover, as for the pulsed laser beam (5), it is also possible to use, for example, a pulsed laser beam by XeF excimer laser (wavelength: 351nm). Also, instead of the glass substrate (1), it is also possible to use a substrate

made of a transparent resin material such as, for example, poly methyl methacrylate (PMMA), polycarbonate or the like.

Also, in the above embodiment, the case where the present invention is applied to a liquid crystal display manufacture is explained, however, the present invention can also be applied to any manufacturing of active matrix type display devices other than liquid crystal displays. For example, where the interlayer insulating film (14) on the pixel electrode (13) in the above embodiment is eliminated, and as for a display material, an electrochromic (EC) material is used instead of liquid crystal, an active matrix type electrochromic display can be manufactured. Furthermore, where a photosensor material is used instead of liquid crystal, a two-dimensional sensor can be manufactured.

[Effect of the Invention]

As explained heretofore, according to the present invention, a high-performance thin film transistor using a cheap glass substrate or resin substrate can be manufactured since an amorphous silicon film is crystallized by irradiating a pulsed laser beam to give it a heat, and at the same time, a source region and a drain region are formed by impurity doping using the irradiation of a pulsed laser beam. Also, the impurity is doped into the silicon film self-alignedly in relation to the gate electrode, the source

region and the drain region of the thin film transistor can be formed self-alignedly in relation to the gate electrode. Moreover, since the lithography process for the formation of the source region and the drain region is not required, at least by this amount, the number of the lithography processes is reduced, thereby the manufacturing processes

4. can be simplified.

Brief Description of Figures

Fig. 1 A through Fig. 1 D are cross sectional views for explaining the process flow of an active matrix type liquid crystal display in one embodiment of the present invention, Fig. 2 is a cornerwise view of a finished liquid crystal display manufactured by the method indicated by Fig. 1 A through Fig. 1 D, Fig.3 is a graph indicating the transmittance spectrum of an as-deposited a-Si:H film and that of this a-Si:H film after it is crystallized by the irradiation of a pulsed laser beam, Fig. 4 is a graph indicating the wavelength dependency of the absorption coefficient calculated from the transmittance spectrums indicated in Fig. 3, Fig. 5 A is a cornerwise view of an example of a conventional active matrix type liquid crystal display, and Fig. 5 B is a cross sectional view taken along the line X-X in Fig. 5 A.

Description of Reference Numerals

1: glass substrate (transparent substrate), 3: a-Si:H film, 6: crystallized Si film, 9: gate bus line, 10: gate electrode, 15: source bus line, T: thin film transistor

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